ECOSYSTEM SERVICES IN AGROFORESTRY SYSTEMS IN EUROPE WITH AN EMPHASIS ON BIODIVERSITY

Kay S[1*], Herzog F[1], Aviron S[2], Crous J[3], Den Herder M[4], Ferreiro Domínguez N[5], Garcia de Jalon S[6], Graves A[6], Moreno G[7], Palma J[3], Plieninger T[8], Szerencsits E[1], Torralba Viorreta M[8], Viaud V[2]

* Correpondence author: Sonja.kay@agroscope.admin.ch

(1) Institute for Sustainability Sciences, Agroscope, Zurich, Switzerland, (2) INRA SAD-PAYSAGE, Rennes Cedex, France, (3) Instituto Superior de Agronomia, Lisboa, Portugal, (4) European Forest Institute, Joensuu, Finland, (5) Universidad de Santiago de Compostela, Lugo, Spain, (6) Cranfield University, Cranfield, United Kingdom, (7) INDHESA, University of Extremadura, Plasencia, Spain, (8) Kobenhavns Universitet, Copenhagen, Denmark

Introduction

Intensive agricultural areas in Europe are confronted with environmental problems such as soil loss by erosion (Tzilivakis et al., 2005), high nitrate concentrations in ground water caused by intensive fertiliser use (Commission, 2013) or biodiversity losses (Tittensor et al., 2014). Introducing trees in open landscape could mitigate these negative effects (Tscharntke et al., 2011). In particular, combining agricultural land with trees as in in agroforestry systems may be beneficial for farmland biodiversity and may improve soil fertility (Pumariño et al., 2015). Furthermore, farmers' can achieve higher productivity per area and a diversification of production (crop & tree). All these mentioned benefits can be summarized as ecosystem services (ES).

In the research project "AGFORWARD", the focus is on ecosystem services of agroforestry systems in Europe. ES can be categorized into regulating and maintenance, provisioning and cultural services. Primarily the regulating services, such as disease regulation or pollination, are closely related to biodiversity. One aim of the project is the assessment of biodiversity and ecosystem services provided by agroforestry at the landscape scale.

Material and methods

ES strongly depend on spatial structures like land cover and land use. However, they are not only linked to single plots, but mostly to landscape structures. Indicators such as landscape diversity or biodiversity, which are composed of ecosystem diversity, species diversity and genetic diversity, need to be evaluated at the landscape scale. For example, the moving corridors of particular species groups such as pollinators or beneficial insects need to be covered. Moreover, the different biographic conditions in Europe need to be taken into consideration.

Therefore, in a first step, in each European biographic region - Mediterranean, Continental, Atlantic and Boreal - typical agroforestry systems (AF) were listed. We distinguished between "AF systems of high nature and cultural value", "AF systems with high value tree", "AF systems for arable lands" and "AF systems for livestock" (Three workshops (WS) were organized between June and September 2014, in Sardinia, Umbria and Veneto with 13, 13 and 22 participants, respectively. In each WS, SHs included representatives of: a) farmers who have already experienced AF systems or farmers willing to start a new AF project; b) professional associations, farm advisors, local policy makers; and c) AGFORWARD researchers.

In the first phase of each WS, participants were invited to talk about their experience and knowledge and to reflect upon the challenges and issues of current AF systems and practices in order to bring information about their opinions and priorities (qualitative data). Then, SHs were invited to fill a questionnaire in which several issues concerning benefits and constraints of AF systems were reported. The list of issues was grouped in the following categories: production (animal health and welfare, qualitative and quantitative productions of crops, animal and trees, etc.), management (mechanization, complexity of work, management cost, etc.), environment (biodiversity conservation, climate mitigation, landscape value, etc.) and socio-economy (income diversity, market opportunity, subside and grant eligibility, etc.). WS participants were

asked to rank each issue with positive or negative score from 1 to 10 according to their perceptions of how AF performs on each issue (quantitative data).

Data analysis

The key issues and challenges identified by SHs were analyzed as qualitative data to highlight the research topics to be addressed, and quantitative data was added by analyzing the responses to the questionnaire. As regards to the latter, the level of importance of an issue was

expressed as Very Important (VI) when the score ranged between 1 and 4, Important (I) (5-7), Less Important (LI) (8-10), and Not Important (NO) when no answer was given. Different weights were assigned to each score: VI = 4; I = 3; LI = 2: NO = 1
The frequency of answers per each score class was calculated as well as the total score obtained from the sum of the frequency multiplied by the value of the relative score class. This analysis was performed in order to assess: i) the differences among the positive and negative total scores by categories of AF issues calculated in relation to the total number of participants (Kruskall-Wallis test, $P \leq 0.1$); ii) the differences among the positive and negative total scores by categories of issues calculated for each SH group, 24 farmers, 17 policy-makers, 7 researchers (Kruskall-Wallis test, $P \leq 0.05$); iii) the difference among the positive and negative scores related to each issue within the group ($\chi 2$ test, $P \leq 0.1$).). Typical systems of AF with high value trees are for example traditional fruit orchards in Switzerland, characteristic AF with livestock are Dehesa in Spain.

Table 1: List of AGFORWARD social catchments

Agroforestry landscape type	Biogeographical regions			
	Mediterranean	Continental	Atlantic	Boreal
AF systems of high nature and cultural value	Cork Oak Montado, Portugal	Wood pasture, Romania	Bocage, France	Oak wood pastures, Sweden
AF systems with high value trees	Olive tree system, Greece	Fruit orchards, Switzerland	Chestnut soutos, Spain	
AF systems for arable lands	Intercrop oaks, Spain	Intensive arable system with trees/ woodlands, Germany	Park land, United Kingdom	
AF systems for livestock	Holm Oak Montado (Dehesa), Spain	Wood pastures, Switzerland		

In each case study region a group of several municipalities was defined as “socio-cultural catchment” (**Figure 1**). In these catchments, landscape test sites (LTS) of one square kilometre each, were selected. LTS represent three major land use types: “Agroforestry (AF)”, “Without Agroforestry (Non-AF)” or if present “Forest (For)”. Each LTS type was replicated four times. For each LTS habitats and trees were mapped, focusing on species, quality and structure. The results of the mapping will build the basis for the computation of ecosystem services. The focus will be on productivity and profitability of trees, crops and animals and on environmental issues like carbon sequestration, nitrate cycle (especially nitrate losses), pollination and landscape diversity.

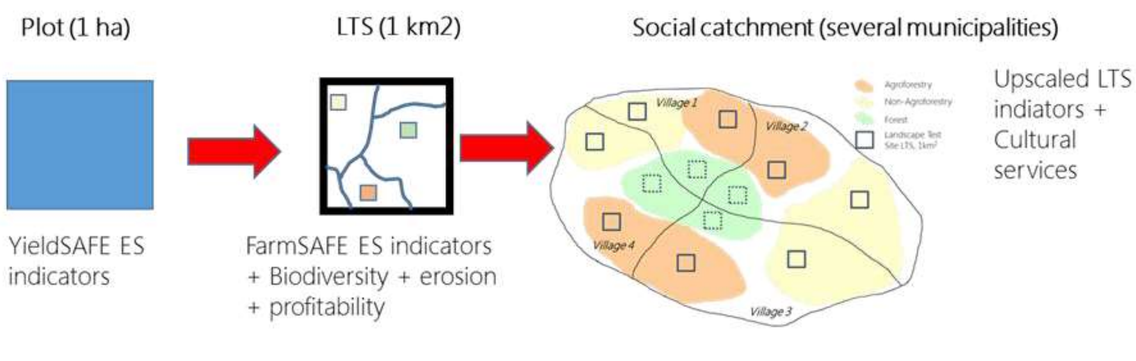

Figure 2: Conceptual approach to scaling and agroforestry ecosystem service modelling in case study regions. LTS: Landscape Test Site.
Productivity will be modelled by using Yield-SAFE (Graves et al., 2010; van der Werf et al., 2007) and profitability by using Farm-SAFE (Graves et al., 2011). Yield-SAFE is a parameter–sparse, process-based dynamic model for predicting growth and productivity of agroforestry

systems. Farm-SAFE is an economic model to compare the net margin, the net present value (NPV) and other indicators of arable, forestry and silvoarable systems. The pollination potential will be based on the InVESTmodel (Lonsdorf et al., 2009). InVEST computes on the flowering and nesting potential together with pollinator abundance the spatial pollination supply. The landscape diversity will be based on Shannon's Diversity index (Shannon, 1948).
The ES indicators will be compared on two levels - among the LTS types themselves and from the perspective of defined scenarios in each case study region. At the level of the social catchment, the ES indicators derived at the LTS will be related to the perception of ecosystem service provisioning by farmers and by the population at large. This perception will be recorded by means of interviews. Interviews will be conducted with a participatory GIS approach, where users indicate the location in the social catchment where they obtain a particular service (Brown and Fagerholm, 2015).
The analysis will reveal (i) differences in ES provision between different land use types, (ii) whether there are trade-offs between different ecosystem services, e.g. profitability versus nature values and (iii) whether the perception of the population of ES provisioning is congruent with the ES indicators as evaluated from the modelling exercise.
In a second step, for every case study region will be evaluated possible alternatives to existing agroforestry systems. Possible changes could be the removal of traditional systems, the establishment of innovative forms of agroforestry systems or modifications of the system like intensification of farming or livestock or structural alterations (**Figure 2**).

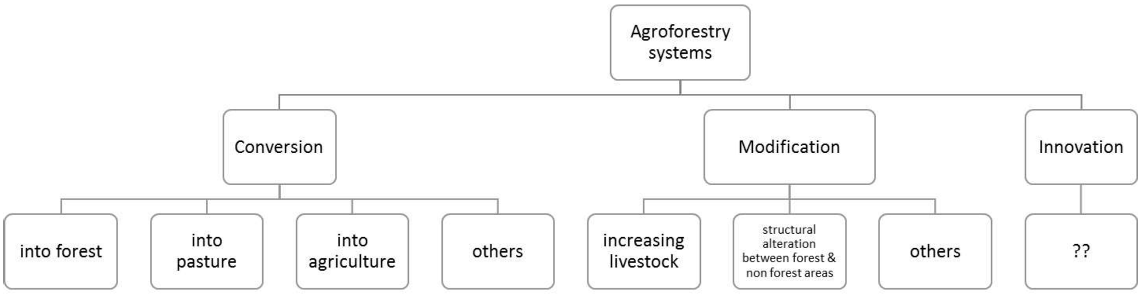

Figure 3: Future development of agroforestry systems – scenarios.

We will calculate different scenarios for each case study region and compare them to the current state and estimated future developments.

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